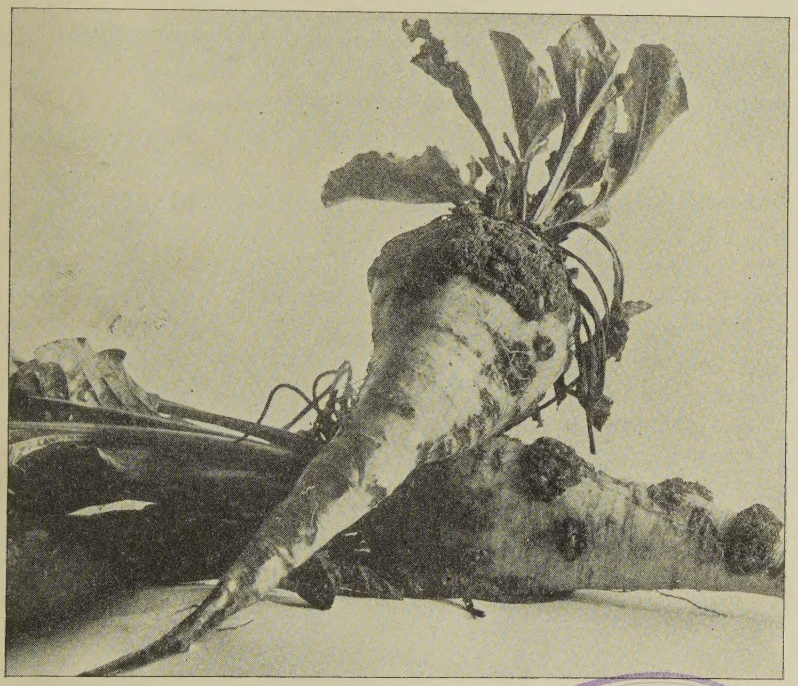
Bulletin 163. **February, 1899.**
Cornell University Agricultural Experiment Station.
ITHACA, N. Y.
BOTANICAL DIVISION.

THREE IMPORTANT FUNGOUS DISEASES OF THE SUGAR BEET.



By B. M. DUGGAR.

IMPERIAL BUREAU OF MYCOLOGY
19 FEB. 1923

PUBLISHED BY THE UNIVERSITY,
ITHACA, N. Y.
1899.

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CORNELL UNIVERSITY, ITHACA, N. Y., Feb. 3d, 1899.

THE HONORABLE COMMISSIONERS OF AGRICULTURE,

ALBANY, N. Y.

Sir:—The great awakening in the production of sugar beets naturally leads to a careful study of the diseases which effect them and which may, in many cases, seriously reduce the yield, therefore, it has been thought wise to make somewhat extended studies of some of the diseases of the sugar beet observed during the past season.

Mr. B. M. Duggar has made most careful investigations and studies of three diseases which are more or less prevalent. An attempt has been made to confine the work largely to those diseases which have proven to be of economic importance in this state. The "root rot" is a new disease in the Eastern states, but in the few localities where it was present during the past year it showed its possibilities for harm, and remedial measures should be at hand. This fungous is of special interest since it may cause diseases of other plants. The leaf spot of beets is ubiquitous in its occurrence, and in many localities it caused severe loss during the past season. The work here presented is the result of work in laboratory and field. The abundance and distribution of the diseases have received special attention in the field studies.

I. P. ROBERTS,

Director.

THREE IMPORTANT FUNGOUS DISEASES OF THE SUGAR BEET.

I. Root-Rot of Beets (*Rhizoctonia Betæ* Kühn.).
   - *a. Occurrence of the Disease.*
   - *b. Appearance of the Affected Plants.*
   - *c. The Cause of the Beet Root-Rot.*
   - *d. Special Characters of the Fungus.*
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II. Leaf Spot of the Beet (*Cercospora beticola* Sacc.)
   - *a. General Account.*
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III. Beet Scab (*Oospora scabies* Thaxter.)
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IV. Some References to the Literature of Beet Diseases.

THREE IMPORTANT FUNGOUS DISEASES OF THE SUGAR BEET.

Many diseases of the sugar beet have been reported in the different countries where this crop is grown, and this is especially true of the old world, where the culture of sugar beets has formed an important industry throughout many years. Already there are three diseases in this state which should be well known to those interested in beet culture. When other diseases appear abundantly, they will also receive merited attention. The widespread distribution of beet culture during the past few years is necessarily attended by a greater distribution of the diseases. It is well at the start to know what these troubles are, and to know the methods of prevention. The losses from plant diseases are often as great, or greater, than losses due to neglect of the proper methods of culture; and as long as we must grow varieties susceptible to fungous diseases, the grower should prepare to combat these disease attacks just as efficiently as he is equipped to fulfil other necessary cultural requirements.

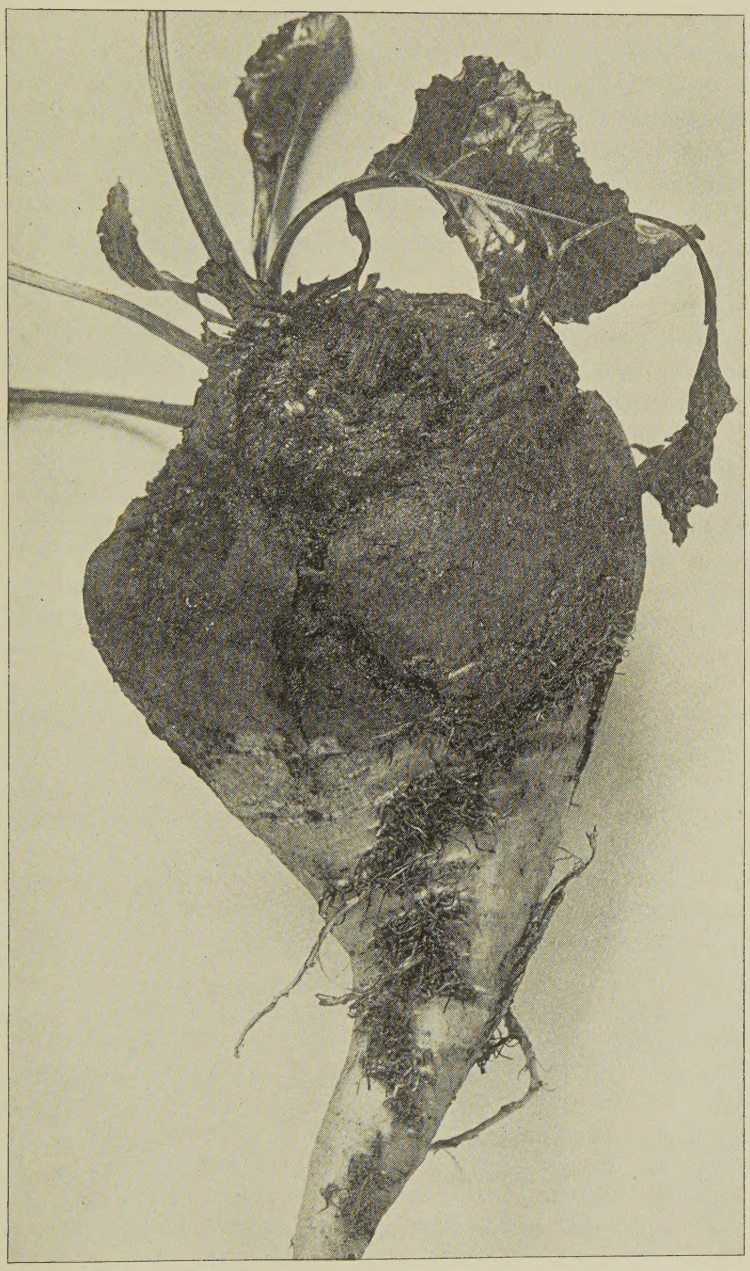
I. Root-Rot of Beets (*Rhizoctonia Betæ* Kühn.)

a. Occurrence of the Disease.

Beet root-rot was first brought to my attention as a disease of small extent in the vicinity of Binghamton. A few days afterwards it was found abundantly at Cattatonk, N. Y. A visit to the latter place on Aug. 12 demonstrated that the disease was a matter of considerable practical importance. An examination of a three-acre field on the premises of Philip Caple convinced me that probably one-third of the beets in this field were affected, and it was then too late to attempt any remedial measures with this root-rot. Fortunately, some change in the conditions soon checked it, and my notes represent the final effect of the disease. A careful study of the affected field showed one point of peculiar interest. In certain areas the chipped tan-bark of an

old tannery had been thickly spread on the land, and in such areas there was not the slightest indication of diseased beets, The tannery product was quite dry; and I attributed the absence of the disease to the lessened water content of the upper layers of the soil, which assumption would be in accordance with the results of some experiments to be detailed later. Again, in a part of the field where coal ashes had been heavily applied, there was a noticeable diminution in the amount of the disease. This disease was afterwards reported from several places in the state, although it has not yet proved a common disease in New York. As mentioned later, what is probably the same disease was reported in Iowa in 1891, and it may have been

49.—*An early stage of the attack of Beet Root-Rot. The basal parts of the leaves are blackened.*



50.—*A late stage of Beet Root-Rot, showing the cracking and rotting of the root.*

observed in one or two other sections of the country. It may be the same trouble that has several times been very destructive to the sugar beet industry in Germany. Again, as subsequently noted, this beet root-rot is caused by the same fungus which causes a stem rot of carnations; and probably by the same fungus which produces some damping off diseases, so that we may predict that it has a wide distribution even at the present time.

b. Appearance of Affected Plants.

Under favorable conditions for its spread, this beet root-rot generally secures its first foothold at the bases of the leaves. These parts are moist with the slightest rain or dew, and inoculation experiments show that in those regions the disease "takes" very readily. The first evidence of the attack is manifest in the blackening of these leaf bases, the outer leaves first, so that the stalks soon become unable longer to support the blades, and the leaves may lie prostrate on the ground. The leaves do not, however, lose their green color very readily. Figure 49 shows this blackening of the leaf bases, before any injury is manifest in the other parts.

The disease soon works into the crown and root proper, causing the infested parts to turn brown. With further spread of the fungus in the root region, cracks appear, as shown in figure 50. If the conditions continue to favor the disease, in time the whole top rots away, and the beet gradually disappears. Cold weather or dry conditions may so retard the disease that plants only slightly affected may recover entirely. Ordinarily the trouble was scattered throughout the entire field affected, but numerous small areas indicate that the fungus passes rapidly from plant to plant in the row, spreading radially.

Even when the bases of the leaves alone are affected, upon careful examination one will find that there are to be seen the brown mycelial threads of the fungus growing over the surface. After the root has become affected, a considerable weft of the fungus will be evident in the cracks. A diseased beet sliced lengthwise and placed in a moist chamber yields in a day or two a luxuriant growth of the mould-like hyphæ. From this outgrowth of mycelium it is very easy to secure a pure culture of

the fungus. Acidulated bean pods, or bean stems, as mentioned by Professor Geo. F. Atkinson, in his study of the sterile damping off fungus,* are excellent for this purpose. The fungus prefers an acid substance, while the ordinary bacteria of decay are shut out by such acidity. One drop of 50 per cent lactic acid to each test tube with the usual amount of medium is sufficient for best results.

If the beets are much rotted, one may find, even in the field, that the surface of roots in moist conditions is covered with a short, tuft-like growth of the fungus. I have not found that the blackened, crust-like, or more or less rounded, compact masses of the mycelium, called sclerotia, ever occur on beets in the field.

In this connection it may be well to state that all necessary cultures were made both from affected parts, and from the adjacent white meat of the beet, to determine the part that bacteria or other fungi might play in the etiology of the disease ; but no other parasitic organism was found. As Pammel has stated, bacteria are probably much concerned in the final rotting of the beet.

c. The Cause of the Beet Root-Rot.

The constant association of the brown fungus *Rhizoctonia* with the cracking and rotting of beets in the field was not taken as final evidence that this fungus caused the trouble, and although late in the season, a few experiments were undertaken to determine the degree of parasitism of the fungus, and the conditions under which it acted.

Experiment 1. In a short row of twenty-four half-grown beets eight were inoculated on Aug. 13. The inoculations were made by placing among the crown leaves fresh pieces of beet on which this fungus alone had been growing for a short time. The whole row was mulched with straw. The weather was wet for a few days only, but afterwards quite dry. On Sept. 2 eighteen beets in this row were affected by the rot.

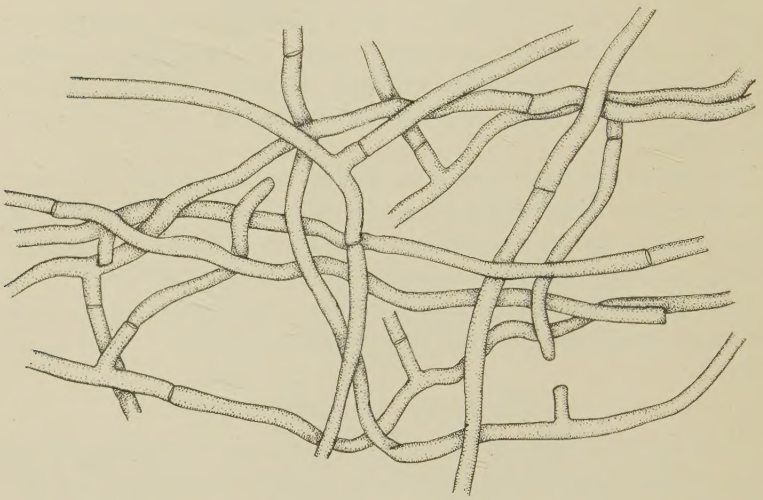
Experiment 2. Six beets or clusters of beets were inoculated as in experiment 1, but over each inoculated area was placed a

* Bulletin 94, Cornell Univ. Agl. Exp. Station, 1895.

large bell glass. On Sept. 2 all of the inoculated plants were diseased, but the trouble had not spread from the bell glasses.

Experiment 3. Twelve beets as above were inoculated, but with no provision for retaining moisture. On Sept. 2 nine of the inoculated plants were affected.

Experiment 4. Twelve beets were inoculated with a mixture of several bacterial forms isolated from diseased tissues and from



51.—*The brown hyphæ which invest the cracks on diseased beets.*

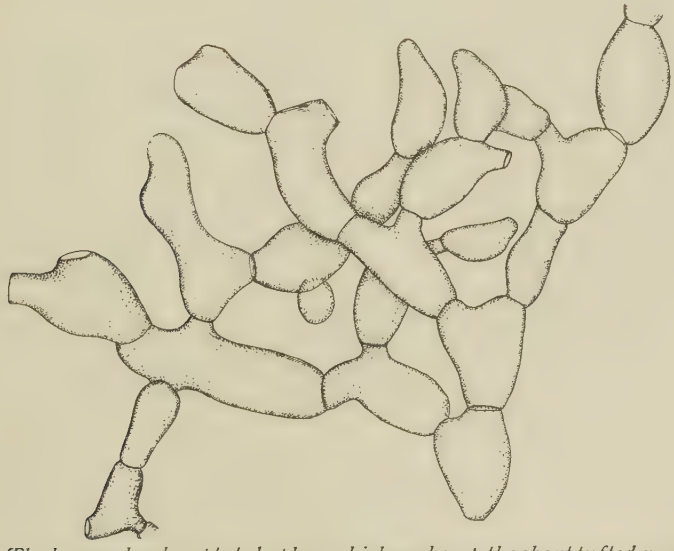
parts of the beet immediately below diseased areas. These beets remained healthy throughout the experiment.

Alternating with the rows experimented upon were check rows, all of the beets in which remained perfectly free from root-rot troubles.

These experiments indicated that the fungus *Rhizoctonia* readily produces root-rot when the conditions are favorable, and that moist conditions are essential for the spread of the disease from plant to plant. Later experiments with pure cultures of the fungus growing on bean pods were used to inoculate seedling beets, and with such plants a damping off effect was produced.

d. Special Characters of the Fungus.

The morphological characters of the fungus may well be studied both from the mycelium found on the diseased beet, and from the growth in pure cultures, secured as above mentioned. In pure cultures on bean pods and on slices of sugar beet the fungus grows vigorously, and a loose mycelium first appears. However the fungus may be grown, it shows a very characteristic method of branching, which serves to identify it. In the young, vigorously growing hyphae the branches are inclined at an angle more or less acute with the direction of growth of the parent branch : and the point of union of the two is marked by a slight constriction. Invariably the branches are cut off by a septum at a distance of several micromillimeters from the parent branch. At first the mycelium is quite hyaline, and



52.—*The large, closely septate hyphae which make up the short tufted growth.*

strongly vacuolate ; but with age the loose hyphae may become very light brown in color. In the older hyphae of the loose growth it is noticeable that the constrictions at the places of union of the branches are not so evident, and this is especially true of the dark colored mycelium found externally in connection with the diseased area of the beet root, as in figure 51. In the cultures the loose growth is followed by a closer tufted growth of short hyphae. On such rich media as bean pods this close growth covers almost the entire surface, and little tufts may also appear on the glass of the test tube. This growth is at first somewhat mealy in appearance, but later it becomes deep brown in color. These tufts are made up of short

hyphae much larger in diameter than those previously mentioned. They are closely septate, and constricted at the septa. Usually they branch irregularly and profusely as in figure 52, but truly dichotomous branching is often observed, and long moniliform chains of cells are not infrequent. Such tufts of hyphae are also occasionally found on beets badly rotted in the field. With age these chain-like aggregations break into hyphal elements of a single cell or of several cells attached; and most of these cells may then function as conidia, producing on germination the characteristic mycelium first mentioned. In the manner of germination these cells are peculiar. The germ tube passes out through the septum originally separating the cell from its neighbor. As soon as the germ tube has grown to an extent equal to several times the length of the parent cell, a septum invariably forms at a short distance from the latter, the proximal cell is somewhat narrowed at its exit from the hyphal cell, and the first septum decides the normal diameter of the tube. When germination takes place from an inner one of several connected cells, a peculiar phenomenon occurs. The germ tube may pass from one cell into and through its adjacent neighboring cell; and usually such cells through which germ tubes pass seem to be themselves devoid of contents, or at least they lack the vacuolate structure of the germinating cells. These characters are shown in figure 53.

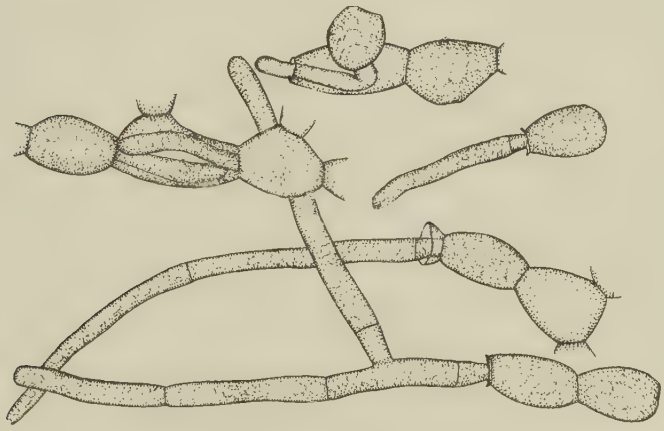
When this fungus is grown on bean stems or on other nutrient media not so rich as bean pods, crust-like sclerotial bodies are oftener formed. The sclerotia begin as a closely branched mass of filamentous hyphae, and by further growth these become so interwoven as to form a more or less compact body. Sclerotia have been more readily produced by making fresh cultures from pure cultures of the fungus which had been kept in the laboratory for a long time, the original cultures being made from damping off lettuce. In all cases, however, the hyphae and the sclerotia are very different from those of *Botrytis* and other allied fungi often causing rots and certain damping off diseases.

e. The Beet Root-Rot Fungus as a cause of Other Types of Plant Diseases.

While working with cotton diseases in Alabama in 1892, Professor Geo. F. Atkinson found that the so-called "sore shin" of seedling cotton plants is abundantly produced by sterile fungus. Some of the results of this work were published in Bulletin 41 of the Alabama Experiment Station. In his later work at this Experiment Station upon damping off fungi, the same fungus was again found to cause damping off of many seedlings, especially of lettuce, cabbage, radish, egg-plant, &c. Under the caption "Damping off by a Sterile Fungus," in Bulletin No. 94 of this

Experiment Station, the fungus was described in considerable detail.

During the past two years I have continued studies upon certain damping off fungi, and this sterile fungus has often been found as the cause of damping off in seedling lettuce, beans, and cucumbers, and occasionally in many other seedlings. That the fungus referred to is the cause of these troubles has been proved in the case of the lettuce and radishes by inoculation with pure culture. Seedlings affected by this fungus show the usual char-



53.—*Germinating cells of the Root-rot fungus.*

acteristics of damping off. The plants first show signs of weakness near the surface of the ground, the water-soaked tissues of this region are soon unable to support the plant, and it may fall prostrate on the surface of the ground, the fungus soon invading all parts. Among lettuce seedlings, especially, this fungus spreads rapidly from plant to plant ; and a box of seedlings may have the appearance of being wilted down, as in figure 54. Damping off diseases of seedlings which have been growing normally should not be confused with the simple wilting of seedlings in dry soil, or to the wilting due to the transfer of seedlings from a warm soil to a cold soil, etc.

In the winter of 1898 I received from a correspondent radishes of marketable size which showed a soft rot of the crown, or ulcerated areas in the region of the crown, as shown in figure 55.

54.—*A box of lettuce seedlings damping off by the sterile fungus.*

The leaves were usually unaffected until large portions of the fleshy roots had rotted. Cultures from diseased parts again yielded a fungus with structural characters exactly similar to those of the sore shin and damping off fungus.

When the beet fungus was first isolated and studied I was surprised to find a fungus agreeing in structural details with the one causing damping off, radish rot, &c. The growth characters of the fungi in pure culture were also practically the same, and experiments were soon instituted to determine if, under any circumstances, the beet fungus could cause damping-off. In the first experiments to determine this point, lettuce and radish seedlings were used. Small pieces of beet on which the beet fungus was growing profusely were put at definitely marked places in a large box of lettuce seedlings on Sept. 26. Similar inoculations were made in a box of radish seedlings, and in both instances checks were observed. On the second day, at every point where the the beet *Rhizoctonia* had been introduced a few lettuce seedlings were diseased, and in five days a considerable area about each piece had damped off. With the radish seedlings damping off was very slow, and no large number of seedlings succumbed; but in seven days a few plants were affected at about one-half of the inoculation centers. Subsequent work seems to indicate that the fungus from beets does not cause damping off of

55.—*Radishes affected with soft rot of the crown.*

a very violent kind, but that it may cause damping off of lettuce, cotton, and some other plants to a limited extent. Owing to the similarity in morphological characters of these forms of *Rhizoctonia* from the sources mentioned, and with the experimental evidence available, it seemed at first that these forms were exactly identical. Further evidence may indicate that we must recognize differences which are at least racial, not permitting of the ready transfer in a single generation of the beet fungus to seedlings of other plants, or vice versa.*

Mr. F. C. Stewart, of the Geneva Station, is at work upon a stem rot of carnations and the fungus causing this disease of carnations is identical in all morphological characters with the *Rhizoctonia* of beet root-rot. Experimental proof has also been established showing that the two diseases are due to the same organism ; and this evidence is detailed in the paper mentioned below.

From the work of Kühn and Pammel it is quite evident that the beet fungus should be referred to *Rhizoctonia Betæ* Kühn ; but at this time it is undesirable to enter into any discussion concerning the proper limitation of species in this genus which has been variously treated by Tulsane†, Comes‡, and others.

f. Remedies.

The use of lime as a possible preventive for certain rhizoctonial diseases has been recommended. The use of an alkali as a preventive might be logically suggested knowing the avidity with which the fungus grows on acidulated nutrient media. The failure of the *Rhizoctonia* to cause trouble in those parts of the field where coal ashes had been used abundantly again suggests the same remedy. Furthermore, Mr. F. C. Stewart has determined that a small amount of alkalinity is fatal

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* Further details bearing upon the similarity of these forms of *Rhizoctonia* will be found in a paper presented before the Society of Vegetable Morphology and Physiology, Dec., 1898, entitled "Different Types of Plant Diseases Due to a Common *Rhizoctonia*," by B. M. Duggar and F. C. Stewart. This paper will soon be published in the Botanical Gazette.

† Tulasne, L. R. & C. Fungi Hypogæi, pp. 188—195.

‡ Comes, O. Crittogamia Agraria.

56.—*A beet leaf showing the early stages of injury due to the leaf spot fungus.* (*Photographed by Prof. Geo. F. Atkinson.*)

to the growth of the *Rhizoctonia* of carnations in cultures. In general it seems that the soils of the State are usually in need of liming, and where this beet disease appears it would be very well to make an application of lime. Sixty to seventy bushels of air-slaked lime per acre would be a cheap and effective means of securing the desired alkalinity. It would be preferable to make this application in the autumn, or at least before the ground is turned, so that the lime would be well distributed.

II. Leaf Spot of the Beet (*Cercospora beticola* Sacc.).

a. General Account.

The above disease is one of very wide distribution. It has long been known both in this country and in Europe, and it probably occurs in all regions where beets are grown even to a limited extent. It is a well known disease of the red garden beet, but many of the garden varieties are so resistant that the disease is not there a matter of great concern. My observations in this State indicate that it is much more injurious to sugar beets, than to the red varieties, and much damage was done by it during the past year. For this reason it needs to be brought to the special attention of those interested in the culture of sugar beets.

The name well denotes the appearance of the disease, at least in the early stages. It begins as small brown spots with a reddish purple margin, these spots being scattered irregularly over the leaf, as in figure 56. The spots become ashen gray at the centers, with the border as before; and they may become so numerous as to cover a large portion of the surface of the leaf before there is any general discoloration of the blade. In time, however, the blade shows a parched appearance, begins to blacken gradually from the distal portions towards the stalk, and finally the whole leaf is black and crisp. As soon as the leaves begin to appear parched and dry, they stand more nearly upright on the crown, and a whole field badly affected with this disease makes a very characteristic appearance, as shown in figure 57. The individual blades that are badly affected are somewhat curled or rolled, and even this is slightly evident in the photograph.

57.—*A field of beets near Owego badly injured by the leaf-spot fungus; the curled and upright condition of the leaves indicate the trouble.*

The outer or older leaves are of course first affected, and after the leaf stalks wilt these leaves are shed. In the meantime the plant is endeavoring to supply this deficiency of leaves by continuing to develop new ones from the center, or from the bud. In consequence of this, the crown becomes considerably elongated, as in figure 58. During the past summer several fields of beets were observed in which the majority of the plants showed crowns thus elongated. If this is very marked, the roots are abnormally small, and much of the energy of the plant is evidently directed to saving itself. Even where the leaves are much less injured, it is undoubtedly a matter of economy to resort to preventive measures.

58.—*Prolonged crown of a beet which has been affected by the leaf-spot fungus.*

During the present season this disease has been especially abundant in the valleys along the streams, but there is every reason to believe that it is usually quite as abundant in the high land as in the low land. In the same field the conditions seem to make but little difference; it is found in the moist basins, and on the well-drained knolls.

Sorauer has stated that the leaf spot fungus is not confined to the leaves, that it is also to be found upon the bracts and peduncles of the flowers, and even upon the seed pods themselves. For this reason he thinks that the disease may be transmitted through the seed so as to be in readiness to affect young seedlings.

b. Characters of the Fungus.

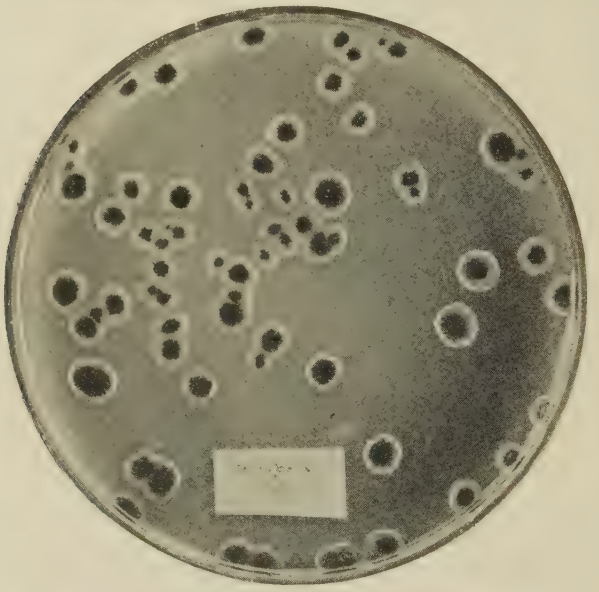
The leaf spot of beets is caused by the fungus *Cercospora beticola* Sacc. When the spots on diseased leaves begin to look somewhat grayish in appearance, the reproductive or propagative parts of the fungus will be found abundantly. The upright blackened leaves often show this ashen appearance over the entire surface. Examining under the microscope a little of this material scraped off with the knife there will be found numerous clusters of short erect hyphae, such as are represented by the darker lower portion of figure 59. These hyphae bear the spores, or reproductive bodies, represented in the upper portion of the figure. These spores are carried about by the wind from diseased leaves to healthy leaves, and from diseased plants to healthy plants; where they fall they germinate, if the conditions are suitable; and on growing again within the tissues of the beet leaf they produce the characteristic spots.

59.—*Fertile hyphae and spores of the leaf-spot fungus.*

The fertile hyphae are about 35–55x4–5.* The conidia vary considerably in size, but are usually 75–200x3.5–4.5,* although much longer if produced in very moist conditions, or in a moist chamber. Pure cultures of the fungus may be readily secured by the ordinary method of dilution culture. The colonies show up well in the petri dishes after a growth of a few days, as shown in figure 60. The mycelium grows in a close mat, deeply olivaceous in color. The aerial growth is also olivaceous at first, and later it is grayish-green. Transfers to sterile bean pods have given excellent growths in pure culture. Cultures of the fun-

* Measurements expressed in micromillimeters.

gus have been kept in the laboratory for two years, and during this time some attempts have been made to secure any other stages that might be connected with the *Cescospora*, but in culture no fruiting forms have been secured. In studies of some other species of *Corcospora* more or less abnormal conidia* were produced, but with this beet fungus not even conidia are developed in cultures. There is a tendency for the aerial hyphae to adhere in clusters as they grow out from the substratum, as in the upper portion of figure 61, and from these hyphae branches arise as if to bear conidia, but none are produced. In the lower portion of figure 61 is represented some of the characteristic mycelium which grows immersed, abundant swellings and irregular branching occurring. A close inspection has been made of old diseased leaves during the autumn and winter, but no fungi have yet been found which seem to suggest a perfect stage of this *Cercospora*.



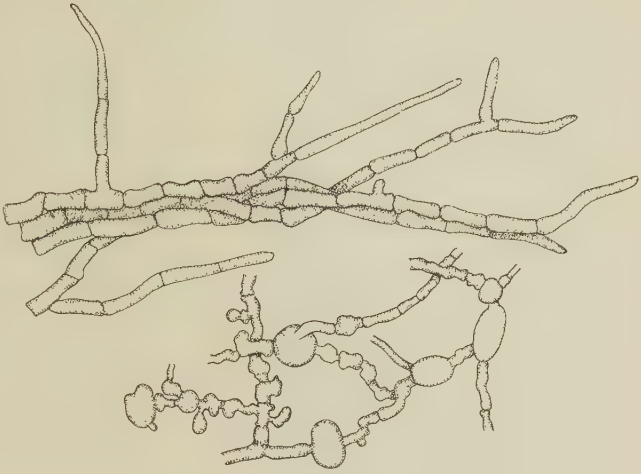
60.—*Petri dish culture of the leaf-spot fungus on agar.*

c. Remedies.

During the past season the serious injuries due to the leaf spot were not manifest until it was deemed too late to make satisfactory experiments with the use of fungicides for its prevention. For several years, however, experiments have been conducted by Professor Halsted, at the New Jersey Experiment Station, in the

*Compare, Early Blight of Celery, Bulletin 132 of this Station.

treatment of this disease, and a successful remedy seems to be at hand in the well-known Bordeaux mixture. Numerous fungicides were experimented upon, but the Bordeaux mixture has proved most efficient.



61.—*Mycelium of Cercospora beticola as grown in pure culture.*

There is every reason to believe that by beginning the sprayings early the leaf-spot may be almost entirely prevented by the use of this fungicide. If the disease continues so disastrous as it was in certain sections during the past season, for success growers must expect to spray their beets with the same regularity as has been found necessary in growing potatoes. The standard formula for the Bordeaux mixture should be used, consisting of:—

Copper sulfate (Blue Vitriol).....	6 pounds
Fresh stone lime (unslaked).....	4 "
Water	50 gallons.

Dissolve the copper in half of the water used, suspending the crystals in a sack in the water.

Slack the lime slowly, and then dilute to half the full quanity of water.

Pour one solution into the other, stirring constantly. Stir the mixture before using. If the potassium ferrocyanide test is not used, it might be well to add another pound of lime.

If by further experiment it should be shown that the disease is introduced abundantly by means of the seed, it will be necessary to treat the seed with hot water, copper sulfate solution, or some

other fungicide. That the seed of beets will readily withstand such treatment is shown in the following table :—

EFFECT OF HOT WATER AND COPPER SULFATE SOLUTION ON GERMINATION OF BEET SEED.

No.	Nov. 4, 100 seed treated with	Time.	Plants germ. Nov. 6.	Plonts germ. Nov. 8, addit.	Plants germ. Nov. 14, addit.	Total germinated, also per cent.
1	Hot water 130°F.....	5 mins.	60	14	3	77
2	" 130°F.....	5 "	11	11	71	93
3	" 130°F.....	10 "	7	28	53	88
4	" 130°F.....	10 "	62	18	12	92
5	Check, water.....	10 "	64	26	9	99
6	" "	10 "	48	15	21	84
7	Copper sulfate. 1–64..	6 hrs.	83	11	3	97
8	" " 1–64..	6 "	80	16	0	96
9	" " 1–128.	6 "	87	10	1	98
10	" " 1–128.	6 "	78	17	0	95
11	Check, water.....	6 "	54	21	13	88
12	" "	6 "	69	10	9	88
13	Copper sulfate 1–64..	18 "	92	7	0	99
14	" " 1–64..	18 "	69	30	0	99
15	" " 1–128.	18 "	91	6	0	97
16	" " 1–128.	18 "	82	13	3	98
17	Check, water.....	18 "	84	3	1	88
18	" "	18 "	50	40	3	93

No.	Nov. 1, 100 seed treated with	Time.	Plants germ. Nov. 24.	Plants germ. Nov. 27, addit.	Plants germ. Nov. 29, addit.	Total germinated, also per cent.
19	Copper sulfate 1– 8..	6 hrs.	75	12	4	91
20	" " 1–16..	6 "	80	16	1	97
21	" " 1–24..	6 "	82	16	1	99
22	" " 1–32..	6 "	71	11	1	83
23	Check, water.....	6 "	66	27	2	95
24	Copper sulfate 1– 8..	18 "	74	25	1	100
25	" " 1–16..	18 "	52	36	1	89
26	" " 1–24..	18 "	62	35	2	99
27	" " 1–32..	18 "	61	32	5	98
28	Check, water.....	18 "	41	33	4	78

In the above experiment nos. 1–18 were germinated on moist filter paper, while with nos. 19–28 moist sand was used. The check lots were soaked for a corresponding period in water,

since soaking the seed is often resorted to in practice. In general, even the strong solutions of copper sulfate gave slightly better results than the water; and germination was often slightly hastened. In a preliminary test, the germination was very markedly in favor of the copper treated seed; but since the conditions were abnormally close and moist, the exclusion of bacteria by the copper solution might have caused the apparently excessive benefit.

It remains to be determined, however, if it is desirable to treat the seed for the prevention of the leaf-spot.

62.—*Beet scab.*

III. BEET SCAB (*Oospora scabies* Thaxter).

a. Appearance of the Disease.

The smooth surface of the beet root may often be disfigured by warty or scabby excresences. The texture of these injuries is somewhat corky or spongy, and the larger diseased areas will show that the injury is not entirely superficial, but to some extent alters the tissues immediately underlying such areas. The frontispiece shows two beets affected in a characteristic manner. The disease begins as small irregularities either widely scattered or clustered. Individual ones spread in extent, and groups often become united, so that in time it may spread over large areas, or small isolated areas may remain. One often notices a tendency for the scabby spots to be arranged in more or

less definite bands, often just at the surface of the ground. The diseased bands, or areas, may, however, appear much lower, as in figure 62. It is very probable that this is determined by soil and moisture conditions. The scabby protuberances are abnormal developments of corky tissue stimulated to excessive growth by the presence of the fungus. Professor Arthur has noted sunken scabby spots on the surface of the beet, and he explains these as early injuries which failed to develop further, when the

63.—*Scabby potatoes.*

conditions were probably unfavorable, and future growth of the beet has left them rather as pits than as excrescences.

b. The Cause of the Disease and Its Prevention.

In 1890 Professor Thaxter discovered that potato scab is caused by the growth on the surface of the tuber of a fungus which he named *Oospora scabies*. When scabby potatoes, such as are represented in figure 63, are placed in a moist chamber, a light,

grayish, mould-like growth of the fungus may appear on the surface; and it was by inoculations with pure cultures of this fungus that he was able to reproduce the disease on healthy tubers. The following year Professor Bolley found the scab of beets abundantly, and the microscopic evidence which he obtained indicated that the fungus was the same in both cases. He furthermore ascertained that in all cases when the beet scab was abundant, potatoes had been grown on the soil, either the previous year or somewhat earlier. Working independently, at about the same time, Professor Arthur came to similar conclusions about the identity of these two forms of scab; and a single decisive experiment in the transfer of scab from potato to beet was reported by him. Since that time there has been abundant general evidence to establish the fact that scabby beets may be expected if the seed are sown on land which has recently produced scabby potatoes. On the College Farm during the past season it has been very significant that the land producing scabby potatoes the previous season, produced scabby beets last season, while infected soil produced beets free from the disease.

The remedy cannot consist in this instance in the treatment of the seed, since the seed do not disseminate the disease; nor can it consist in the treatment of the land, since the experiments with liming, sulfuring, etc. have not given satisfactory results. The only course open, then, is the one of avoiding for the growth of beets any soil, which, during several years previous, has produced scabby beets.

B. M. Duggar.

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